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BULLETIN

OF THE

AMERICAN PHYSICAL SOCIETY

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PROGRAMME OF THE

CLEVELAND MEETING

AT

CASE INSTITUTE OF TECHNOLOGY

March 10–11–12, 1949

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MARCH 10, 1949 Vol. 24, No. 3

BULLETIN

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AMERICAN PHYSICAL SOCIETY

CLEVELAND MEETING, MARCH 10–11–12, 1949

THE 291st meeting of the American Physical Society will be held at the Case Institute of Technology and Western Reserve University in Cleveland, Ohio, on Thursday, Friday and Saturday, March 10, 11, and 12, 1949. This will be a meeting largely devoted to solid-state physics; our Division of the appropriate name has organized a Symposium extending over three half-day sessions, and the presence of two longish sessions of contributed papers in the same field attests its success in attracting solid-state physicists to Cleveland. Nuclear physics and other departments of physics provide between them only two sessions of ten-minute papers, possibly because the reservoir was drained by the oversized New York meeting. To redress the balance in part, a session of invited papers on topics diversely chosen has been arranged; fluid dynamics will be represented by a speech on Thursday evening to which the Cleveland Physics Society invites our members. Not more than two sessions will be simultaneous at any time, and the Friday sessions of the Symposium have been kept clear of competition. This moderate meeting should provide a delightful contrast with that which will have gone before and that which is to follow.

The **Hollenden Hotel** reserved a quota of rooms for our members, undertaking to hold them available until March first; ample notice of this deadline has already been given. If this Bulletin does not appear before March first, members who did not heed the earlier notices must trust to their own devices.

The **Case Institute of Technology and Western Reserve University, may be reached from the Hollenden Hotel** by going south on East Sixth Street to Euclid Avenue, crossing Euclid Avenue and taking (in front of the west end of Taylor's Department Store) a bus which is marked "Euclid Express No. 28." Get off at Adelbert road. Allow thirty minutes.

The **registration desk will be set up in Rockefeller Physics Laboratory** of the Case Institute of Technology; all members and guests are asked to register, and to consult frequently the blackboard on which messages are indicated.

The **Symposium of the Division of Solid-State Physics** will be held in the Allen Memorial Library Auditorium on the Western Reserve Campus on Thursday afternoon and Friday; the speakers will be A. P. de Bretteville, I. Estermann, J. E. Goldman, F. S. Goucher, Eugene Guth, Charles Kittel, K. G. McKay, A. W. Lawson, E. Orowan, G. E. Pake, Frederick Seitz, C. S. Smith, and Roman Smoluchowski. The Business Meeting of the Division of Solid-State Physics will take place at the end of the Friday morning sessions.

The **invited papers on the general programme** are by K. K. Darrow, L. L. Foldy, Isabella Karle, and J. H. Williams; they are grouped in a session on Thursday morning.

The **Cleveland Physics Society invites our members to a lecture,** "Turbulent fluid motion challenges the physicist," **by H. L. Dryden,** to be given under its auspices on Thursday evening at 8:15 in the Allen Memorial Library. Opportunity to dine in the vicinity before this lecture will be provided.

FEB 28 1949

The **banquet of the American Physical Society** will be held in the Hollenden Hotel on Friday evening at 7:00. The price will be $3.25, including taxes and tips. Advance reservation should be made by use of the form on the inside back cover page. Tickets will be sold at the registration desk; the Society reserves the right to sell uncalled-for and unpaid-for tickets after 3:00 on Friday afternoon.

The Council of the American Physical Society will meet on Saturday morning at 10:00 in Conference Room B of Tomlinson Hall, Case Institute of Technology, unless contrary notice is received by its members.

Post-deadline papers. The Council or its designates will consider the admission, to a special supplementary programme, of a limited number of papers of which the abstracts are received not later than Saturday 5 March. This privilege is reserved for descriptions of very recent results of outstanding importance, and is definitely not meant as an outlet for belated papers. The abstracts of such post-deadline papers as are accepted will not be printed; the titles will be announced on a blackboard at the registration desk, and the papers will be scheduled for presentation at the end of Session F.

Prospective meetings of the Society are planned as follows: Washington, D. C., April 28–30; Cambridge, Massachusetts, June 16–18 (Semi-Centennial Meeting); Seattle, Washington, June 27–29. It may become a painful necessity to restrict the admission of papers to the Washington meeting, lest the flood of papers overtax the available halls.

Errata in the Membership List. The asterisks designating Andrew Gemant, M. L. Huggins, and Paul Klopsteg as Fellows were unfortunately omitted in the Membership List lately issued.

General Rules Relating to Papers

The time allowed for the oral presentation of a contributed paper is ten minutes at most. The time allowed for the oral presentation of each invited paper is stated in the Bulletin.

When two or more papers are contributed by the same member, all but one are placed on the "supplementary programme." (A paper by two or more members is credited, for this purpose, to the first person named on its by-line.) For each paper on this programme a session is indicated at the end of which it may be offered; but the presiding officer may require that it be given in fewer than ten minutes, or may read it by title.

Proofs of the abstracts hereinafter printed have not been submitted to the authors, who however have opportunity to correct their proofs before the abstracts appear in the *Physical Review*. Overlong abstracts sometimes appear in a form unexpected by the authors, who for want of time are not consulted before the abstracts are amputated to fit the requirements stated on the summons card.

Karl K. Darrow, *Secretary*
American Physical Society
Columbia University
New York 27, New York

EPITOME OF THE MEETING

(Names are those of invited speakers.)

Thursday Morning

A. L. L. Foldy, J. H. Williams, I. Karle, K. K. Darrow. Allen Memorial Library Auditorium.
B. Contributed papers on solid-state physics. Physics Lecture Room.

Thursday Afternoon

F. Papers not classed elsewhere. Physics Lecture Room.
G. Symposium of the Division of Solid-State Physics: E. Guth, G. E. Pake, C. Kittel, J. E. Goldman. Allen Memorial Library Auditorium.

Thursday Evening

Meeting of the Cleveland Physics Society: H. L. Dryden. Allen Memorial Library Auditorium.

Friday Morning

K. Symposium continued: R. Smoluchowski, E. Orowan, F. Seitz, F. S. Goucher. Business Meeting of the Division of Solid-State Physics. Allen Memorial Library Auditorium.

Friday Afternoon

L. Symposium continued: I. Estermann, C. S. Smith, A. W. Lawson, A. P. de Bretteville. Allen Memorial Library Auditorium.

Friday Evening

Banquet of the American Physical Society. Hollenden Hotel.

Saturday Morning

U. Order-disorder, structure, magnetism, semi-conductors. Tomlinson Hall Ballroom.
V. Nuclear physics. Physics Lecture Room.

PROGRAMME

THURSDAY MORNING AT 10:00

Allen Memorial Library Auditorium

(F. W. LOOMIS presiding)

Address of Welcome by President T. Keith Glennan, Case Institute of Technology.

Invited Papers

A1. Electromagnetic Properties of Nucleons. L. L. FOLDY, *Case Institute of Technology.* (30 min.)

A2. Nuclear Scattering. J. H. WILLIAMS, *University of Minnesota.* (30 min.)

A3. Studies of Internal Motion and Molecular Structure by Electron Diffraction. ISABELLA KARLE, *Naval Research Laboratory.*

A4. Linguistics of Solid-State Physics. K. K. DARROW, *Bell Telephone Laboratories.* (30 min.)

THURSDAY MORNING AT 10:15

Physics Lecture Room

(A. W. LAWSON presiding)

Contributed Papers on Solid-State Physics

B1. Thermal Expansion of $Li_2SO_4 \cdot H_2O$. CHARLES S. SMITH AND H. H. LANDON, *Case Institute of Technology.*—The complete thermal expansion characteristics of the monoclinic crystal $Li_2SO_4 \cdot H_2O$ have been determined by x-ray diffraction measurements of thermal strains in a number of crystallographic directions for the temperature interval $-30°C$ to $+25°C$. The thermal expansion coefficient in an arbitrary direction in the crystal is given by $\alpha_{33}' = C_{13}^2\alpha_{11} + C_{23}^2\alpha_{22} + C_{33}^2\alpha_{33}$, where the α's are the principal expansion coefficients and the C's are the direction cosines of the arbitrary direction with respect to the principal axes. The results are, in units of 10^{-6} reciprocal °C, $\alpha_{11} = 16.3$, $\alpha_{22} = 27.5$, $\alpha_{33} = -2.9$ with $\psi = 2.7°$. The direction of α_{11} lies at angle ψ with respect to the c axis of the unit cell[1] and in the obtuse angle between c and a. The direction of α_{22} is, by symmetry, the b axis of the unit cell. The thermal expansion is thus negative in a 45° range roughly normal to c in the $a-c$ plane.

[1] G. E. Ziegler, Z. Kristallogr. **89**, 456–461 (1934).

B2. Primary and Secondary Pyroelectric Effect in Lithium Sulfate Monohydrate. HANS JAFFE, *The Brush Development Company.*—Data on thermal expansion of lithium sulfate crystals[1] permit calculation of the secondary pyroelectric effect, i.e., the piezoelectric moment due to a set of stresses that would produce elastic strains equal to the thermal expansion. Further information needed are the piezoelectric coefficients relating to the polar axis for which we found $d_{21} = -4.0$, $d_{22} = 16.0$, $d_{23} = 1.5$, $d_{25} = -5.3 \cdot 10^{-12}$ coulomb/newton, and several elastic constants.[2] The resulting secondary pyroelectric constant is $21 \cdot 10^{-6}$ coulomb/m² °C, while the observed total pyroelectric effect[3] is $76 \cdot 10^{-6}$ coulomb/m² °C. The strong electromechanical coupling in lithium sulfate (about 0.35) therefore accounts for only 30 percent of its exceptionally high pyroelectric effect.

[1] C. S. Smith, preceding paper.
[2] Some of these were obtained privately from W. P. Mason.
[3] *International Critical Tables* VI (McGraw-Hill Book Company, Inc., New York), p. 212.

B3. Propagation of Elastic Waves in Some Cubic Crystals as a Function of External Pressure. DAVID LAZARUS, *University of Chicago.*—Measurements of velocity of sound in single crystal specimens of CuZn, KCl, and NaCl have been made, using a pulsed ultrasonic technique, over a pressure range of 10,000 bars. From observation of the velocities of longitudinal and transverse waves in both (100) and (110) crystals of each material, the elastic constants can be computed, with two internal checks. The measured percentage change in velocity of sound for 10,000-bars pressure is given for various velocities in the table. Good correlations are found between computed compressibilities and those measured by Bridgman. The decrease in

Material	Longitudinal $V_{(100)[010]}$ (%)	Longitudinal $V_{(110)[011]}$ (%)	Transverse $V_{(100)[010]}$ (%)	Transverse $V_{(110)[011]}$ (%)
CuZn	+1.83	+1.77	+1.59	+1.21
KCl	+14.9	+10.0	−3.71	+15.8
NaCl	+12.5	+7.0	+1.05	+12.6

the (100) 010 shear velocity for KCl can be explained by consideration of short-range exchange forces, as shown by Zener.* Comparison is made between pressure effects and the previously measured effects of temperature on elastic constants.

* C. M. Zener, Phys. Rev. **71**, 846 (1947).

B4. Apparatus for Rapid Measurement of Internal Friction. HERBERT I. FUSFELD, *Frankford Arsenal.*—This paper describes apparatus for measuring internal friction which satisfies the conditions: (a) low induced stress amplitude to preclude any effects due to the measurements, (b) ability to install specimen within a few minutes after treatment, (c) rapidity of measurement, at a rate of ten to twenty per minute, (d) accuracy of at least 1 percent. Longitudinal vibrations are induced by an eddy-current drive, similar to one previously described in the literature,[1] satisfying (a) and (b) above. Conditions (c) and (d) are obtained by measuring the decay time of free vibrations using vacuum tube trigger circuits and a counter chronograph. As the counter records times on the order of 0.010 second with considerable accuracy, satisfactory measurements can be made with push-button rapidity and simplicity.

[1] R. H. Randall, F. C. Rose, and C. Zener, Phys. Rev. **56**, 343 (1939).

B5. A Calculation of the Effects Produced by Soluble Impurities on the Damping of Metals. J. S. KOEHLER, *Carnegie Institute of Technology.**—The ideas of Cottrell[1] and of Mott and Nabarro[1] are used to calculate that portion of the damping which is associated with plastic deformation. It is assumed that the damping arises from an interaction of a moving dislocation with the crystal lattice. It is assumed that this interaction gives rise to a constant amount of energy loss each time a dislocation of unit length moves through one atomic distance. The dislocations are taken to be anchored at the impurity atoms in the manner proposed by Cottrell. The application of an external alternating stress then causes the portion of the dislocation between two impurity atoms to oscillate on its slip plane much like a stretched string. The resonant frequency for such a system is calculated very roughly to be in the megacycle range. The damping in the kilocycle range is calculated to vary inversely as the square of the concentration of impurities; hence the large effects of traces of hydrogen on the damping of copper and of bismuth on the damping of lead can be understood. It is pointed out that at very low frequencies the force exerted by dislocations under external stress on the impurity atoms may lead to a motion of the impurity atom.

* This research was supported by the ONR.
[1] A Conference on the Strength of Solids (Bristol Conference) London Physical Society (1948).

B6. Effect of Dissolved Hydrogen on the Decrement and the Elastic Constants of Copper.* J. MARX, *Carnegie Institute of Technology.*—Measurements made on the damping and elastic constants of single crystals of 99.999 percent copper shows that samples, grown and previously annealed to constant decrement in vacuo, exhibit a very marked decrease in decrement when heated in dry hydrogen at 500°C. Decrements were observed to change from 4.8×10^{-2} to 5.7×10^{-4} at strain amplitudes of 2.5×10^{-7}. A simultaneous *increase* of about 3 percent occurred in the axial Young's modulus of the specimens. This latter change is in the opposite direction to that observed by Koster[1] for the case of *metallic* impurities in copper.

* This research was supported by the ONR.
[1] W. Koster and W. Ravscher, Zeitz, f. Metallkunde **39**, 111 (1948).

B7. Longitudinal Vibration of Bars with Non-Linear Internal Friction. A. S. NOWICK, *Columbia University.*—In investigations of internal friction of plastic origin,[1] the measured decrement of crystalline bars has been found to be dependent on amplitude of vibration. This result means that the partial differential equation of motion of the bar is non-linear. Thus far, it has always been assumed implicitly that this equation of motion can be linearized with negligible error. To test this assumption a Maxwell model with non-Newtonian dashpot is chosen and the appropriate non-linear integro-differential equation for longitudinal motion is derived. An approximation method is described for solving this equation for the case of steady-state forced vibration near a resonant frequency, under the assumption of small damping. It is found that all odd normal modes appear. Approximate numerical solution for the amplitudes of the first three modes is then obtained on the assumption of dissipative velocities proportional to the third, fifth, and seventh powers of the applied stress. It is found that the equation of motion cannot be linearized to good approximation if powers higher than the third appear appreciably in the relation between dissipative velocity and applied stress. The analogous calculation for a more general model is briefly discussed.

[1] See, for example, T. A. Read, Phys. Rev. **58**, 371 (1940).

B8. On the Mechanism of the Embrittlement of Copper by Bismuth. T'ING-SUI KÊ, *University of Chicago.*—The embrittlement of copper by small amount of bismuth has been known for many years. Voce and Hallowes[1] proposed recently that the agent responsible for embrittlement is bismuth present in the form of a thin film at the grain boundaries of copper. In order to examine this picture from a different angle, measurements on internal friction and elastic modulus were made on copper specimens free from and containing bismuth. These specimens were heat-treated to cause embrittlement according to Voce and Hallowes. Measurements were made with a frequency of transverse vibration of about 1000 cycles per second from −50°C to 550°C. It has been found: (1) There is no abrupt change in elastic modulus of the copper-bearing specimens in passing through the melting point of bismuth (271°C).

(2) Each bismuth-bearing specimen gives an internal friction peak around 290°C and the height of the peak varies approximately linearly with the bismuth content. (3) The internal friction peak (around 500°C) associated with the stress relaxation across copper grain boundaries was reduced by the presence of bismuth. These observations indicate that the bismuth causing embrittlement of copper does not form a thin film along copper grain boundaries.

[1] E. Voce and A. P. C. Hallowes, J. Inst. Metals **14**, 323 (1947).

B9. Precipitation from Supersaturated Solid Solutions of C and N in α-Iron.* CHARLES A. WERT, *The University of Chicago.*—The formation of precipitates from the solid solutions of C and N in α-iron has been studied by means of the internal friction peak associated with the interstitial diffusion of the solute atoms. A transformation law of the type first proposed by Johnson and Mehl[1] for recrystallization has been found to fit the experimental data. The data are interpreted as showing the following: (1) Fe_3C precipitates in the shape of spheres; (2) an intermediate phase in the precipitation of nitrogen forms in the shape of disks; (3) there is no incubation time for nucleation of these precipitates; and (4) within experimental error there is no continuous nucleation. Using the results of a derivation made by Zener (as yet unpublished), the mean distance between nuclei is calculated for Fe_3C. This distance is found to be about 800, 2000, and 7000 angstroms at 27°C, 102°C, and 312°C, respectively. With appropriate experimental conditions the temperature dependence of the precipitation rate is found to be about the same as the temperature dependence of the diffusion rate of the solute atoms.

* This research was supported by the ONR.
[1] Johnson and Mehl, "Reaction kinetics in processes of nucleation and growth," AIME **135**, 416 (1939).

B10. The Diffusion of Carbon in Alpha-Iron. JAMES K. STANLEY, *Westinghouse Research Laboratories* (*Introduced by* J. E. Goldman).—The diffusion of carbon in alpha- (body-centered cubic) iron was determined using two methods. The first method consisted of diffusing carbon from a saturated well (actually fine pearlite; carbon content 0.7 percent) into an essentially carbon-free material. The second method consisted of diffusing carbon from a "high" carbon sample (0.008 percent) to a sample of lower carbon (0.001 percent), both samples being in the ferritic phase. Both methods gave similar results when the carbon distribution curves were analyzed by Fick's law of diffusion. The data can be represented by the following equation: $D=3.8\times10^{-3}e^{-(16{,}800/RT)}$ cm²/sec. The diffusion coefficient of carbon in alpha-iron is considerably faster than that for carbon in gamma iron;[1] for example, at 725°C the diffusion coefficient is about 125 times greater.

[1] C. Wells and R. F. Mehl, AIME **145**, 279 (1941).

B11. Plastic Deformation of Crystals. DONALD WAHL, *Massachusetts Institute of Technology.*—A review of past work on plastically bent single crystals (primarily NaCl) showed a great deal unexplained. In the past, crystals were bent without regard to uniformity during deformation. Attention was paid only to the end product (that is, an arc of a circle). A simple device has been built to bend crystal specimens uniformly at speeds and to radii within wide ranges. Preliminary x-ray investigations of deformed crystals (primarily alkali halides) by the Laue transmission method, have been found inconclusive. Instead it appears that a series of exposures taken with a monochromatic beam, making different angles with the crystal "face," yields more information through a type of specialized pole figure for nearly perfect single crystals. It is expected that with the use of these new tools a better understanding of the processes allowing deformation will be obtained.

B12. Mechanism of Steady-State Creep in Metals. B. G. RIGHTMIRE, *Massachusetts Institute of Technology.*—The experimental results of Dushman[1] show that in the steady-state creep of metals the logarithm of the strain rate varies linearly with stress. From the slopes of these curves he deduces that the unit of flow comprises about 1000 atoms. It is here pointed out that Dushman's values of energy of activation suggest that the unit of flow contains only about 10 atoms. To explain this apparent contradiction it is proposed that the flow units are dislocations that move segmentally, rather than as rigid structures. Each segment is assumed to be one atomic diameter in length. It is postulated that if one of these segments jumps to a new position of equilibrium the others follow in tandem. With the aid of this concept, absolute-reaction-rate theory enables one to estimate the number of atoms per dislocation, and the concentration and velocity of the dislocations. Computations have been made for aluminum, silver, and platinum. It is found that aluminum contains relatively few, fast-moving dislocations, which may account for the observed slip bands.

[1] S. Dushman, L. W. Dunbar, and H. Huthsteiner "Creep of metals," J. App. Phys. **15**, 108–124 (1944).

B13. Surface Energies for a Free Electron Metal. H. B. HUNTINGTON, *Rensselaer Polytechnic Institute.*—If one chooses as an idealized model for a metal a region enclosing free electrons with a square barrier, the expression for the surface energy turns out to be relatively independent of barrier height, providing the barrier is so placed that there is no excess or deficit of electrons. The value so obtained, however, is more than twice a corresponding result calculated for a particular metal, sodium, using the self-consistent potential developed by Bardeen.[1] The same procedures are applied to the situation of two metal surfaces separated by a displacement comparable to the distance between planes of closest packing. Particular attention is paid to the cohesive forces between the surfaces. A possible application exists if a supersaturated solution of lattice vacancies in a metal should precipitate to form a plate-like void. From a knowledge of the cohesive forces one can estimate an upper limit to the size to which such a plate might grow before collapsing.

[1] J. Bardeen, Phys. Rev. **49**, 653 (1936).

THURSDAY AFTERNOON AT 2:30

Physics Lecture Room

(E. HUTCHISSON presiding)

Papers Not Classed Elsewhere

F1. Transition Temperatures of Methyl Methylmethacrylate Polymers at Ultrasonic Frequencies. THOMAS F. PROTZMAN, *Ohio State University.*—The velocity of sound in methylmethacrylate polymers (Plexiglas) has been measured at temperatures from 24 to 90°C, and frequencies from three to eleven megacycles. Optical diffraction methods were used to determine the sound velocity within a maximum error of 1 percent. This low experimental error made possible a detailed study of the sound velocity-temperature relationships. A previously unreported transition of a new type has been found. The sound velocity decreases linearly with increasing temperature, with an abrupt increase of slope occurring when a transition temperature is reached. The transition temperature is found to decrease linearly with frequency, falling from 64°C at three megacycles to 49°C at eleven megacycles. The observed transitions apparently are not manifestations of elastic relaxational effects, and are tentatively attributed to the excitation of some mode of molecular motion, for example, molecular vibrations.

F2. Measurements of Ultrasonic Absorption in Viscous Liquids. JOSEPH L. HUNTER, *John Carroll University.*—Measurements of ultrasonic absorption in several liquids ranging in viscosity from 40 to 400 cp have been made in an interferometer having an air-liquid interface as a reflector.[1] The measurements are interesting in that the absorption coefficient appears to be, if anything, *lower* than that predicted by Stokes from the shear viscosity of the liquid, although probably within the experimental error. Consequently, the dilatational term mentioned by Liebermann[2] as an explanation of the "anomalous" absorption values in liquids, does not seem to be present in high viscosity liquids. The frequency used was 1.75 mc. At this frequency, almost total absorption could be readily accomplished in path lengths shorter than 40 centimeters.

[1] J. L. Hunter, Phys. Rev. **74**, 1228 (1948).
[2] L. N. Liebermann, Phys. Rev. **73**, 537 (1948).

F3. The X-Ray K-Absorption Edge of Calcium in the Metal and Some Compounds. MARCELLA COOPER PETREE AND W. W. BEEMAN, *University of Wisconsin.*—The calcium K-absorption edges of the element and of $CaCl_2$, CaF_2, $Ca(OH)_2$, and calcite have been measured using a double crystal vacuum spectrometer and Geiger counter recording. The resolving power was about 0.3 e.v. in the 3-angstrom region. The absorption edge of calcium metal shows fair agreement with the single crystal photographic work of Sanner,[1] and displays a remarkable complexity of structure in comparison with the potassium edge.[2] The curves for the compounds exhibit the similarities to be expected among examples of ionic binding. The fact that the spectrometer was equipped with calcite crystals made it possible to investigate the shift of the reflection curve with respect to the absorption curve of calcite in a region of anomalous dispersion. The shifts observed were of the order of 2 e.v.

[1] Hugo Sanner, *Thesis*, Upsala (1941).
[2] J. B. Platt, Phys. Rev. **69**, 337 (1945).

F4. On the Existence of Micelles in Organic Acid Monolayers. H. T. EPSTEIN, *University of Michigan.*—Electron micrographs of fatty acid monolayers show an organization of the molecules into clusters, or micelles, of the order of 100A in diameter. Because the substrates used have had irregularities of the same order of magnitude, the establishment of the micelle as a property of the monolayer molecules must be based on the observation of systematic variations in the micelles as external conditions are correspondingly varied. Such variations have now been observed; the micelle diameter, for example, is found to vary with the length of the molecule. Additional evidence is available from electron diffraction experiments, and these results will be included in a summary of the evidence for the reality of the micelles. A model for the structure within a micelle has been developed which permits the calculation of relationships between the micelle diameter, the length of the molecules, and the characteristic tilt of the molecules as measured by electron diffraction. Predictions of the model have been tested and a qualitative agreement between theory and experiment has been obtained.

F5. A Sector Type Double Focusing Magnetic Spectrometer. E. S. ROSENBLUM, *Case Institute of Technology.*—The analysis, by Shull and Dennison,[1] of the motion of electrons in an annular magnetic field which varies approximately with $1/r^{\frac{1}{2}}$, has been extended to allow the field to cover an arbitrary sector, and to allow arbitrary location of the source outside the field. Considering small variations from equilibrium values, in the coordinates and momentum of incident particles, it is found that an image of a source can be obtained in the space beyond the field boundaries. An analogy to a thick-lens optical system is developed, from which the location of principal points, coordinates of conjugate foci, the magnification and dispersion can be determined. A second order analysis gives more information on image size and resolution. It is found that with any given field angle and equal object and image distances, the magnification and dispersion are the same as that given by Shull and Dennison,[1] and the resolution is of the same order of magnitude. For smaller object distances, image size and dispersion both increase, so that the resolution varies only slightly. However, the flexibility of the instru-

ment, accessibility of source and counter, and their location in field-free space, should make the instrument a useful one.

[1] Shull and Dennison, Phys. Rev. **71**, 681 (1947).

F6. Noise Spectrum Analyzer.* B. R. RUSSELL, R. DICKSON, AND P. H. MILLER, JR., *University of Pennsylvania.*—An analyzer having twelve band-pass amplifier channels each with its own square law detector and indicator has been set up for the purpose of measuring flicker noise (noise power per c.p.s. $\alpha\nu^{-1}$) in the range 10^2 to 5×10^5 c.p.s.[1] Day to day calibration is achieved by means of the shot noise from a 931A photo-multiplier tube which has instead of a load resistor an RC network adjusted so that its impedance varies nearly as $\nu^{-\frac{1}{2}}$ in the range covered by the instrument. In this way the frequency independent shot noise of the photo-multiplier[2] is attenuated to match the flicker type noise for which the instrument was designed. Results of the measurements of the noise in crystal rectifiers, electrolytic condensers and tired batteries will be presented.

* This work supported by Bureau of Ships, US Navy.
[1] R. H. Thomas, Technical Report No. 8, February 1, 1948, BuShips Contract NObs-34144.
[2] R. D. Sard, J. App. Phys. **17**, 768 (1946).

F7. High Current Pulse Generator Using Mechanical Energy Storage, R. I. STROUGH AND E. F. SHRADER, *Case Institute of Technology.*—Construction of a high current d.c. generator of the series unipolar type employing no iron in its magnetic "circuit" is in progress. This machine is being studied as a possible energy storage system for an air core betatron, and as a possible cloud chamber field supply. The rotor of the machine serves as a flywheel for energy storage and is driven up to speed between current pulses by means of compressed air jets acting on turbine buckets cut in the rotor. The present model employing a $5\frac{3}{4}$ inch diameter rotor weighing 11 lbs. will store 64,000 joules at 30,000 r.p.m. quite safely. To obtain the negative resistance characteristic necessary for current build-up in the machine, it is essential that the brush resistance be kept extremely small. For this reason a brush system employing mercury flowing between amalgamated surfaces is being investigated. Static model tests indicate that such brushes may be operated at current densities of the order of 10^4 amperes per square cm with a contact resistance of the order of a few micro-ohms cm^2.

F8. New Phenomena of Radiation in Magnetic Fields. FELIX EHRENHAFT, *University of Vienna, Austria.*—The initiative for the following experiments the results of which are well known in full extent since Christmas 1947 has been given by the hypothesis of unipolar magnetic charge. F. Ehrenhaft, R. F. K. Herzog, M. J. Higatsberger, F. P. Viehböck, and P. M. Weinzierl found, using the metallic connected north and south pole of an electromagnet as cathode of a gas-discharge, that besides the gas-discharge between cathode and anode a radiation becomes visible and can be photographed reaching from pole shoe to pole shoe; the pole shoes have to be covered with a thin layer of some isolating material f.i. apiezon-oil. Under these conditions this radiation becomes visible in discrete light traces following the direction of the magnetic lines of force. This radiation is not caused by high frequent oscillations[1] and it also exists if the space between the pole shoes is surrounded with a Faraday-cage to screen off the influence of the electric field of the anode. Under certain conditions one part of the radiation between the poles forks to the anode. A sufficient explanation of these phenomena by means of moving electric charges is not possible. At my institute F. Blaha and J. A. Schedling using as cathode a permanent magnet got the same results.

[1] A. Righi, Physik. Zeits. **11**, 158 (1910) and **15**, 529 (1914); J. Ives, Phys. Rev. **9**, 349 (1917).

F9. The Electron Does Not Exist. BAYARD P. PEAKES.—The discovery of the electron was apparently a sound advancement in theoretical physics. But let's review the conditions under which it exists. The beam in the cathode ray tube was first thought to be light, until it was found that it could be bent by electric or magnetic fields. The beam's reaction to magnetic and electric fields identified the rays as being composed of tiny particles having a negative charge, electrons. Yet, these electrons occurred only when the pressure in the tube was about 10^{-3} mm Hg. When there was no air in the tube, conduction was most difficult, and there were no electrons. Hence, if a certain pressure is needed for electrons, these electrons must be derived from that air, and be the cause of them. A complete, careful study of electrical phenomena will reveal electricity as being some form of kinetic energy. Conductors, or maintainers of it, are hot glass, a flame, or light. Electricity *could* be a wave disturbance, made by intermittent attraction between magnet and copper conductor. After many months of working over physics books, one can get this definition of electricity: it is a supersonic motivation, of necessity a wave disturbance, and is created and persists only where there is a contrast, or potential difference, between two points in its line of propogation.

THURSDAY AFTERNOON AT 2:30

Allen Memorial Library

(F. W. LOOMIS presiding)

Symposium of the Division of Solid-State Physics

G1. Ferromagnetism and Rubber Elasticity. EUGENE GUTH, *University of Notre Dame.* (45 min.)

G2. Nuclear Magnetic Resonance in Studies of Solids. G. E. PAKE, *Washington University.* (30 min.)

G3. Recent Developments in Ferromagnetism. CHARLES KITTEL, *Bell Telephone Laboratories.* (30 min.)

G4. Influence of Atomic Order on Magnetic Properties. J. E. GOLDMAN, *Westinghouse Research Laboratories.* (30 min.)

THURSDAY EVENING AT 8:15

Allen Memorial Library

Meeting of the Cleveland Physics Society

(R. S. SHANKLAND presiding)

Turbulent Fluid Motion Challenges the Physicist. H. L. DRYDEN, *National Advisory Committee for Aeronautics.*

FRIDAY MORNING AT 10:00

Allen Memorial Library

(W. SHOCKLEY presiding)

Symposium (continued) of the Division of Solid-State Physics

K1. Recent Developments in Knowledge of Order-Disorder Phenomena. R. SMOLUCHOWSKI, *Carnegie Institute of Technology.* (30 min.)

K2. Brittle Fracture of Triaxial Stresses. E. OROWAN, *Cambridge University.* (30 min.)

K3. Multiplication of Electrons in Crystals by High Electrostatic Fields. F. SEITZ, *Carnegie Institute of Technology.* (30 min.)

K4. Some Electrical and Photoelectric Studies of $p-n$ Junctions in Silicon and Germanium. F. S. GOUCHER, *Bell Telephone Laboratories.* (30 min.)

Business Meeting of the Division of Solid-State Physics

FRIDAY AFTERNOON AT 2:30

Allen Memorial Library

(F. SEITZ presiding)

Symposium (continued) of the Division of Solid-State Physics

L1. Resistivity of Germanium Samples at Liquid Helium Temperatures. I. ESTERMANN, *Carnegie Institute of Technology.* (30 min.)

L2. Grain and Interphase Boundaries in Metals. C. S. SMITH, *University of Chicago.* (30 min.)

L3. New Techniques in High-Pressure Research. A. W. LAWSON, *University of Chicago.* (30 min.)

L4. Optical Interference Phenomena and Cinema-Micrography of Barium Titanate Crystals. A. P. DE BRETTEVILLE, N. J. FIELD, AND S. B. LEVIN, *Squier Signal Laboratory.* (25 min.)

FRIDAY EVENING AT 7:00

Hollenden Hotel

(F. W. LOOMIS presiding)

Banquet of the American Physical Society

SATURDAY MORNING AT 10:00

Tomlinson Hall Ballroom

(R. SMOLUCHOWSKI presiding)

Order-Disorder, Structure, Magnetism, Semi-Conductors

U1. Short Range Order in Cu_3Au.* J. M. COWLEY, *Massachusetts Institute of Technology*.—At temperatures greater than the critical temperature, the long range order of Cu_3Au is zero but considerable short-range order remains. This short-range order gives rise to a diffuse scattering of x-rays with maxima at the positions of the sharp super-structure reflections given by the ordered lattice. A three-dimensional Fourier analysis of the diffuse scattering power, plotted as a periodic function in reciprocal lattice space, gives directly the short-range order coefficients α_{lmn} which determine the probability of either copper atoms or gold atoms being at the lattice points with coordinates l, m, n with respect to a given atom. Values of these short-range order coefficients have been calculated from measurements of the intensities of x-ray scattering from a single crystal of Cu_3Au held at various temperatures above the critical temperature, using a Geiger counter spectrometer with a bent-crystal monochromator. The results indicate a tendency for like and unlike atoms to arrange themselves in alternate shells about a given atom with a distribution analogous to that of atoms in a liquid. The dependence of the short-range order coefficients on temperature, and their relation to long range order are discussed.

* Supported in part by the ONR.

U2. Structure and Short Range Order for Low Temperature Ag_3Al.* B. W. ROBERTS, JR., *Massachusetts Institute of Technology*.—The low temperature phase of Ag_3Al has been reported in space group O^7-P4_13 as simple cubic with random positioning of the twenty atoms per unit cell. The atom arrangement was reported identical with that of beta-manganese and several isomorphous alloys all of which have valence electron to atom ratios of 3:2. In an investigation of the short range order in Ag_3Al a forbidden line and several intensity changes were observed on powder x-ray diffraction photographs. These dictated a change in space group to lower symmetry and an adjustment of the atom positions. The new space group was found to be T^4-P2_13 with twenty atoms in two (4a) and one 12(b) equivalent positions. Since a satisfactory intensity agreement is obtained from a random arrangement of the 15 Ag and the 5 Al atoms in the twenty cell positions, there is no evidence for a long range order in Ag_3Al. Measurements of total diffuse x-ray scattering from flat powder samples indicate that a small amount of short range order exists in low temperature Ag_3Al.

* Supported in part by the ONR.

U3. Long Range Order in β Brass.* B. E. WARREN AND D. CHIPMAN, *Massachusetts Institute of Technology*.—A single crystal of β-brass cut parallel to (100) is mounted in a heating unit on a Geiger counter spectrometer. Using either crystal monochromated CuKα or CuKβ radiation the integrated intensity of the superstructure line (100) is measured at various temperatures up to T_c. Comparison with (111) of NaCl shows the long range order to be nearly perfect at room temperature. With increasing temperature the measured long range order drops continuously to zero at T_c. The drop is somewhat steeper near the critical temperature than the variation predicted from current theories. The use of crystal monochromated CuKβ rather than CuKα radiation increases the integrated intensity of (100) β-brass by a factor of 4, but does not give as accurate a measure of long range order because of the uncertainty in $(f_{Zn}-f_{Cu})$.

* Supported in part by the ONR.

U4. Superlattice Lines of the Second Kind and Their Relation to the Apparent Discrepancy in the X-Ray Analysis of the Structure of Heusler Alloy. LOUIS GOLD, *Brown University*.—A new aspect of order-disorder transformations has been uncovered in connection with what at first appeared to be a discrepancy in the x-ray analysis of the structure of Heusler alloy. It was found that the assigned structure* could not account for the weak series of lines as characteristic of the ordered form of the alloy. An explanation which accounts for the odd index lines of the weak series appearing not only as a distinct group, but also with considerably lower intensity than the even index superlattice lines, is to be associated with what may be termed superlattice lines of the second kind. These lines are attributable to intermediate order only, vanishing when

the alloy is completely ordered or disordered. An analysis of conditions for the existence of superlattice lines of the second kind reveals that the effect is a perfectly general one and is not limited to Heusler alloy. Systems in which atoms have several degrees of freedom for interchange may be expected to exhibit diffraction lines characteristic of the intermediate state of order, the actual occurrence of such superlattice lines being predictable from an examination of the structure factor for any degree of order.

* A. J. Bradley and J. W. Rodgers, "The crystal structure of Heusler alloys," Proc. Roy. Soc. London **144A**, 340–359 (1934).

U5. Structure of Ferroelectric $BaTiO_3$.* G. C. DANIELSON AND R. E. RUNDLE, *Iowa State College.*—Megaw has shown from x-ray powder photographs that $BaTiO_3$ is tetragonal in the ferroelectric state with unit cell dimensions at 20°C of $a_0=3.9946$A, $c_0=4.0335$A. It has been shown* by x-ray diffraction of a single domain crystal that at 20°C the titanium ion is displaced from the center in the direction of the c-axis by about 0.16A, in agreement with the displacement to be expected from Hulm's measurement of the spontaneous polarization. Recently, Mason and Matthias have used this displacement of the titanium ion in developing a theory to explain the ferroelectric behavior of $BaTiO_3$. The previous x-ray determination was based on the relatively high intensity of x-ray scattering from the (00 11) plane as shown by a Weissenberg pattern using molybdenum radiation. Since (00 11) is the highest order obtainable with Mo radiation, one could not be certain that the (00 13) reflection did not also have a relatively high intensity. This point can be settled only by using a shorter wave-length radiation. Using Ag radiation from a demountable gas tube, and single domain crystals grown by E. G. Grimsal and F. A. Halden (using Matthias' method), we have confirmed the previous results and have also shown that the (00 13) reflection does not have a high intensity. We can conclude that the displacement of the titanium ion at 20°C is not less than 0.16A nor greater than 0.20A. The most probable value is 0.18A.

* This work was done in part in the Ames Laboratory of the Atomic Energy Commission.

U6. An X-Ray Investigation of Iron-Rich Iron Tungsten Alloys. DAVID D. VAN HORN, *Case Institute of Technology.*—Debye-Scherrer diffraction patterns in the back-reflection region have been used to investigate the solid-solubility of tungsten in iron. Standard techniques have been used, with modifications in some cases, to obtain accurate determination of lattice parameters. Incidental to these determinations of the lattice parameter of alloys of various compositions, the lattice parameter of pure α-iron (at 20°C) was found to be $a_0=2.8603_1=0.00004kX$ units, which is in essential agreement with Jette and Foote.* The lattice parameter *vs.* composition curve of the α-phase iron-tungsten solid solution has been obtained. It has been possible from this information to determine the variation in the solubility of tungsten in iron with temperature in a number of solution heat treated and aged iron-tungsten alloys.

* Jette and Foote, J. Chem. Phys. **3**, 605 (1935).

U7. The Limiting Sensitivity of Instruments for Displaying the Magnetic Hysteresis Loops of Small Specimens. E. C. CRITTENDEN, JR. AND R. I. STROUGH, *Case Institute of Technology.*—The factors limiting the ultimate attainable sensitivity have been studied and an instrument constructed which approaches this limit. The instrument is of the type which displays on a CRO screen the integrated signal from a pair of bucked flux coils *vs.* the magnetizing field. Circuit noise at the preamplifier input and at the integrator output and the perfection of balance of the two flux coils limit the usable sensitivity. Since the preamplifier signal is multiplied by $1/\omega$ because of integration, low frequency noise reduction is important. Use of electrometer tube circuits in the preamplifier reduces integrated noise output 45 db. A magnetizing current wave form containing first and third harmonics with adjustable amplitude and phase reduces the number of Fourier components in the signal for most specimens. This greatly reduces the integrator noise difficulty by permitting higher preamplifier gain and reducing the band width needed in the second amplifier. Special construction of magnetizing and flux coils reduces stray field noise. The instrument as constructed gives a signal equal to noise for 1.5×10^{-4} Maxwells flux change.

* This work was supported by the ONR.

U8. Microwave Magnetic Resonance Absorption in Chrome Alum at 1.25 cm. W. A. YAGER, F. R. MERRITT, A. N. HOLDEN, AND C. KITTEL, *Bell Telephone Laboratories.*—Magnetic resonance absorption at a frequency of 24,446 mc/sec. was observed in a crystal of ammonium chrome alum at room temperature as a function of the intensity of the static magnetic field applied in the [111] direction. Previous measurements have been reported on this salt at lower frequencies, by the Oxford, Rutgers, and Pittsburgh groups. We observed five absorption lines, at 7210, 8220, 8770, 9220, and 10,290 oersteds. Using the theory given by Broer[1] and by P. R. Weiss[2] we find a g-value of 1.99 from the position of the central line; while from the difference of the lowest and highest lines we find a zero field energy level splitting of 0.143 cm^{-1}. The results are in good agreement with theory and with results reported by other workers at lower frequencies.

[1] L. J. F. Broer, Physica **9**, 547 (1942).
[2] P. R. Weiss, Phys. Rev. **73**, 470 (1948).

U9. Quantum Theory of Ferromagnetic Resonance. J. M. RICHARDSON, *Bell Telephone Laboratories.*—Luttinger and Kittel[1] have given a quantum mechanical derivation of the Kittel equation (first derived classically), $\Delta E=g\mu_B(BH)^{\frac{1}{2}}$, giving the separation between large adjacent eigen values of the Hamiltonian for a plane specimen of ferromagnetic material with the static field parallel to the plane. They actually used the more general Hamiltonian for an elliptical specimen $\mathcal{H}=aJ_z+bJ_z^2+cJ_x^2$, in which J_z and J_x are the x and z components of the angular momentum operator, and in which the 1st term arises from the static field applied in the x direction and the 2nd and 3rd terms arise from demagnetizing effects. Their derivation was based upon the approximate solution of the secular

equation using an explicit representation in which J_z is diagonal. In this paper it is shown how to derive the result more simply using formal operator algebra and no explicit representation. First, the commutators of $\mathcal{H}$ with J_y and J_z are computed. Assuming $J_z \simeq \langle J_z \rangle_{Av} 1$, these commutators can be linearly combined so that $[J_y \pm i\alpha J_z, \mathcal{H}] = \mp \hbar\omega (J_y \pm i\alpha J_z)$, in which $\omega = (a+2(b-c)\langle J_z \rangle_{Av})^{\frac{1}{2}}(a+2b\langle J_z \rangle_{Av})^{\frac{1}{2}}$, which is just the classical relation, and $\alpha = (a+2(b-c)\langle J_z \rangle_{Av})^{\frac{1}{2}}(a+2b\langle J_z \rangle)^{-\frac{1}{2}}$.

[1] J. M. Luttinger and C. Kittel, Helv. Phys. Acta. **21**, 480–482 (1948).

U10. Conductivity of Sintered and Single Crystals of Zinc Oxide Semiconductor.* E. E. HAHN, B. R. RUSSELL, AND P. H. MILLER, JR., *University of Pennsylvania.*—Room temperature measurements of electrical conductivities, σ, and Hall constants, R, give carrier mobilities $\sim$100 to 200 cm^2 volt^{-1} sec.$^{-1}$ in single crystals of ZnO[1] and $\sim$5 to 60 cm^2 volt^{-1} sec.$^{-1}$ in sintered samples.[2] σ and the sample type show no correlation. Measured by usual methods, poorly sintered samples invariably show low σ and are usually frequency dependent ($\nu \sim 10^7$ c.p.s.). Sintered samples therefore probably consist of semiconducting microcrystals surrounded by lower conductivity layers; measured conductivities are largely determined by the layers. Theory of measurement[3] of R indicates the layers negligibly affect R because of the shorting-out effect of the microcrystals; measured R values for sintered samples are therefore characteristic of the microcrystals. Assuming the mobility in a single crystal having dimensions $\sim$0.1 cm is the same as in a sintered sample microcrystal having the same number of impurities, the experimental discrepancy in mobilities is attributed to erroneous σ values and indicates that σ of sintered ZnO microcrystals cannot be determined accurately by usual methods.

* Work supported by Bureau of Ships, USN.
[1] Supplied by New Jersey Zinc Co., Palmerton, Pa.; spectroscopic check indicates presence of lead impurities.
[2] For other measurements see P. H. Miller, Jr., Phys. Rev. **60**, 890 (1941); O. Fritsch, Ann. d. Physik **22**, 375 (1935).
[3] I. Isenberg, B. R. Russell, and R. F. Greene, Rev. Sci. Inst. **19**, 684 (1948).

U11. Theory of Photovoltaic Effect of $P-N$ Barrier in a Semi-Conductor. H. Y. FAN, *Purdue University.**—Sosnowski has treated the $P-N$ barrier on the basis of penetration of the barrier by electrons. Such treatment applies to very narrow barriers with thickness comparable to the mean free path of the electrons. We shall consider thick barriers where the diffusion theory applies. If the activation energies of both types of impurities are so small that they are almost completely ionized, a condition true for germanium over wide temperature range, then we can write for the divergences of electron (i_1) and hole current (i_2) in the barrier $-(1/e)(di_1/dx) = (1/e)(di_2/dx) = H + L - rn_1n_2$, where H is the rate of transition (per unit volume) of electrons from the filled band to the conduction band under thermodynamical equilibrium conditions, L is the rate of additional transition (per unit volume) due to light absorption, r is the recombination coefficient of conduction electrons and holes, n_1 and n_2 are the concentrations of conduction electrons and holes respectively. It can be shown that if the light beam is wide compared with the barrier thickness then the change in potential difference between the two boundaries A and B of the barrier due to the illumination is: $\Delta V_{AB} = \log(n_{1A}'n_{1B}^0/n_{1B}'n_{1A}^0) = \log(n_{2B}'n_{2A}^0/n_{2A}'n_{2B}^0)$, where superscript zero refers to the normal condition and superscript prime refers to the condition under illumination. If the increase in n_1 and n_2 is small compared with normal values of n_1 in the N region and n_2 in the P region of the semiconductor, then the open circuit photovoltage is given by: $V_P = (kT/e)\log(H+L/H)$.

* This work was assisted by a Signal Corps contract.

U12. Theory of Resistivity and Hall Effect in Semi-Conducting Anisotropic Crystals.* V. A. JOHNSON, *Purdue University.*—In anisotropic crystals the effective mass of a free electron (or hole) has a tensor characteristic. This property of the mass produces a tensor character in the resistivity, which has been investigated experimentally[1] and also theoretically.[2] By extending the treatment of tensor resistivity due to Bronstein, explicit expressions are obtained for the tensor resistivity in an intrinsic semiconductor (both holes and electrons) and also for the resistivity due to scattering by ionized impurities; the latter is influenced by the tensor properties of both mass and dielectric constant. Derivation of the Hall effect in anisotropic crystals shows that the Hall coefficient is independent of crystal orientation in the magnetic field as long as carriers of one sign only are present, but the Hall coefficient will have a directional dependence if both holes and electrons conduct and if the effective mass ratio has a directional dependence.

* This work was assisted by a Signal Corps contract.
[1] V. E. Bottom, Bull. Am. Phys. Soc. **24** (January) 1949.
[2] M. Bronstein, Physik. Zeits. d. Sowjetunion **2**, 28 (1932).

U13. Photovoltaic Effect of $P-N$ Barriers Produced in Germanium by α- and Deuteron Bombardment.* M. BECKER AND H. Y. FAN, *Purdue University.*—$P-N$ barriers can be created in N-type germanium by α- or deuteron bombardment of a part of the surface.[1] The photovoltaic effect has been studied quantitatively for a number of such barriers.[2] The experimental arrangement consisted of a 100 watt Western Union Concentrated Arc whose light was first focused on a rotating slotted disk which passed light pulses of 0.001 sec. at a 0.006 duty cycle. It was then made parallel and passed through fixed diaphragms whose diameters determined the intensity of the final light spot which was 1 mm in diameter. The open circuit photovoltage pulses were amplified and displayed on an oscilloscope. It is found that excluding the visible light by a No. 88 Wratten filter has little effect upon the magnitude of the photovoltage, hence the effective spectral region is in the infra-red. Over a range of 1:1024 in intensity and a range of 1:104 in photovoltage, the equation derived by one of the authors in an accompanying paper $e^{\alpha V/kT} - 1 = \alpha I$, is closely satisfied for all the barriers studied. In the above equation V is the open circuit photovoltage and I is the light intensity and α a constant.

* This work was assisted by a Signal Corps contract.
[1] K. Lark-Horovitz, E. Bleuler, R. Davis, and D. Tendam, Phys. Rev. **23**, 1256 (1948).
[2] The authors wish to thank Mr. J. Forster for preparing some of the samples.

U14. Resistivity of Germanium Samples at Liquid Helium Temperatures. I. ESTERMANN, A. FONER, AND J. E. ZIMMERMAN, *Carnegie Institute of Technology.**—The resistivity of several germanium samples with different amounts of added impurities was measured between 4°K and 20°K. Samples with high impurity content, in which the electron gas is degenerated below 100°K, do not change their resistivity in this temperature range. Another sample, which has a degeneracy temperature of 20°K, computed from Hall Effect measurements, showed the same behavior. Two other samples, which did not become degenerate above 20°K, exhibited a moderate increase in resistivity (20 and 80 percent respectively) between 20°K and 4°K. Two "pure" samples, i.e., without added impurities, showed a very strong increase of resistivity below 20°K, increasing from about 2 ohm-cm at 20°K to more than 3×10^5 ohm-cm at 4.7°K. At these low temperatures, however, the resistance depends strongly on the applied electric field, and this effect requires further study.[1]

* This paper is to be given as L1 in the Symposium; the abstract is printed here for the record.
[1] Work assisted by the ONR and the Research Corporation.

SATURDAY MORNING AT 10:15

Physics Lecture Room

(R. S. SHANKLAND presiding)

Nuclear Physics

V1. Preliminary Investigation of Radiations from I^{124}. J. LAWRENCE MEEM, JR. AND FRED MAIENSCHEIN, *Indiana University.*—I^{124} (4-day) was made by bombarding antimony with 23-Mev alpha-particles in the Indiana University cyclotron. Absorption of positrons in aluminum indicate a beta-ray end point of 2.45 Mev. Coincidence absorption of Compton electrons ejected from aluminum show that the maximum energy gamma-ray is approximately 2 Mev. Beta-gamma-coincidences are present and the number of beta-gamma-coincidences per recorded beta-ray is independent of the energy of the beta-rays. This work was assisted by the joint program of the ONR and AEC.

V2. Disintegration of Iodine^{131}. DANIEL J. ZAFFARANO, ALLAN C. G. MITCHELL, AND BERNARD D. KERN,* *Indiana University.*—The beta- and gamma-rays of I^{131} obtained from Oak Ridge have been examined with a magnetic lens spectrometer. Gamma-rays of energy 80, 163, 282, 363, and 637 kev have been found, of which all except the last one are internally converted. The beta-end point is 605 kev, and a plot using exact Fermi functions indicates a second group at 238 kev with perhaps a third at lower energy. The gamma-ray at 163 kev is weak and was not reported by Metzger and Deutsch,[1] but was found by Owen, Moe, and Cook.[2] A decay scheme similar to that given in reference 1 is proposed which gives better agreement with our measurement of the energy of the second beta-group and incorporates the 163-kev gamma-ray also reported in reference.[2] This work was assisted by the joint program of the ONR and the AEC.

* Atomic Energy Commission Fellow.
[1] F. Metzger and M. Deutsch, Phys. Rev. **74**, 1640 (1948).
[2] G. Owen, D. Moe, and C. Cook, Phys. Rev. **74**, 1879 (1948).

V3. Coincidence Studies on Au^{199}. FRED MAIENSCHEIN AND J. LAWRENCE MEEM, JR., *Indiana University.*—The activity of Au^{199} (3.3 days), obtained from Oak Ridge, has been studied by absorption and coincidence counting techniques. Absorption of the beta-rays in aluminum indicate a beta-ray end point of 0.32 Mev. Coincidence absorption of photoelectrons give an energy of 0.211 Mev for the highest energy gamma-ray, in agreement with Peacock and Wilkinson.[1] A small, but definitely positive, gamma-gamma-coincidence rate was observed. The beta-gamma-coincidence rate was found to be independent of the energy of the beta-rays. Coincidences between internal conversion electrons and beta-rays indicates that the most energetic conversion electrons have an energy of about 120 kev. A search was made for a metastable state of Hg^{199} growing from Au^{199}. There is no evidence for the formation of a state of half-life 43 min. formerly attributed[2] to Hg^{199}. This work was assisted by the joint program of the ONR and the AEC.

[1] L. A. Beach, C. Peacock and R. Wilkinson, Phys. Rev. **75**, 211 (1949).
[2] M. Friedlander and C. Wu, Phys. Rev. **63**, 227 (1943); R. Sherr, K. T. Bainbridge, and H. H. Anderson, Phys. Rev. **60**, 473 (1941).

V4. Energy Distribution of Fission Fragments from U^{235} and U^{233}. D. C. BRUNTON AND G. C. HANNA, *Chalk River Laboratory.*—Measurements have been made of the energy distributions of fission fragments from U^{235} and U^{233} irradiated with slow neutrons. A coincident pulse technique was employed using a double "back-to-back" ionization chamber. The chamber was filled with $A+3$ percent CO_2 and pulses were obtained by electron collection with Frisch grids shielding the collecting electrode. Pulses lying in a fixed energy interval were selected in one side of the chamber by an electronic "gate" and the energy distribution of the coincident pulses in the other side was measured on a thirty-channel pulse analyzer. Runs with a wide open gate yield the normal double-peaked curve of fragment energy distribution. A narrow energy gate was moved progressively across the double peaked curve and for each

setting the coincident distribution was measured. These gated distributions are surprisingly independent of the gating energy. The mean position and the width of the distribution shift only a few Mev for a 20-Mev change in gating energy. A comparison of the fragment energies[1] for U^{235}, U^{233}, and Pu^{239} will be given. The asymmetry of the fission process appears to decrease with increasing mass number of the fissile nucleus. The total kinetic energy is found to be a maximum at a mass ratio of 1.25.

[1] M. Deutsch and M. Ramsey, MDDC-945.

V5. Range Distribution of the Charged Particles from the $D-D$ Reactions for 10-Mev Deuterons: Differential Elastic Scattering Cross Section at 40 Degrees, 30 Degrees, and 20 Degrees in the Laboratory System. L. Rosen, F. K. Tallmadge, and J. H. Williams, *Los Alamos.*—Photographic plates were used to determine the range distribution of all charged particles from the $D-D$ reactions as well as the absolute intensity of the elastically scattered deuterons for 10-Mev deuterons from the Los Alamos cyclotron. These measurements were made at 40 degrees, 30 degrees, and 20 degrees (laboratory coordinate system) with respect to the incident beam which was focused on a "thin" deuterium gas target 15 feet from the cyclotron. At 40 degrees all of the charged particles from above reactions (protons, tritons, He^3's, and elastically scattered deuterons) were clearly resolved. At 20 degrees the triton and deuteron mean ranges differed by less than three percent and hence could not be resolved. Slit systems were used to define the number of tracks originating in a given swath across the photographic plate. This, together with the high degree of resolution of scattered deuterons from other charged particles (at 20 degrees the energy width at half-maximum of the scattered deuterons was three percent), permitted precise determinations of the differential $D-D$ scattering cross section. Accurate determinations of beam direction, beam energy, maximum beam energy spread, and purity of target gas were made from the same plates which yielded the cross-section determinations.

V6. Angular Distribution of Photo-Neutrons.* Edwin P. Meiners, Jr., David R. Smith, and Lewis Slack, *Washington University.*—A study has been made of the angular distribution of photo-neutrons obtained by the action of Na^{24} γ-rays (2.76 Mev) on deuterium under approximately ideal conditions of low neutron scattering. Sources of Na^{24} of about one curie initial activity were prepared by bombarding metallic sodium with deuterons in the Washington University cyclotron. A BF_3 ionization chamber was used as detector, which together with the source, was hung from a frame tower on top of the Washington University physics building. Results were obtained at 0° and 90° angles for three glass spheres, 0.95, 1.27, and 1.50 cm in diameter, filled with D_2O; and extrapolation made to a sphere of zero diameter. The final calculation gives a value for the ratio of the photo-magnetic cross section to the photoelectric cross section $\sigma_m/\sigma_e=0.286 \pm 0.034$, a value which is in excellent agreement with theory. This work was confirmed by repeating the measurements using, as method of neutron detection, the Szilard-Chalmers reaction in calcium permanganate solution. This latter method possesses the advantage of being completely insensitive to γ-rays. Work is now in progress on the angular distribution of photo-neutrons from beryllium bombarded by Na^{24} γ-rays.

* Assisted by the ONR.

V7. Depolarization of Neutrons During Diffusion. Otto Halpern, *University of Southern California.*—Rigorous[1] or asymptotic[2] solutions of the transport equation for neutrons incident upon a plate of infinite or finite thickness have been used to determine the change in polarization of the reflected and transmitted beams. The method is particularly suited to the physically most interesting case of small depolarization per collision. The solutions of the transport equation obtained differ by varying amounts (15 percent to 100 percent) from those given by Borowitz and Hamermesh.[3] The intensities of the reflected and transmitted beams are in many cases of practical interest (thickness$\sim$5–10 mean free paths) of the same order of magnitude contrary to the statements of the authors quoted. Measurement of the depolarization of returning beams seems most promising in some cases; formulae for this effect are given for every angle of return.

[1] O. Halpern, R. Luneburg, and O. Clarke, Phys. Rev. **53**, 173 (1938).
[2] O. Halpern and R. Luneburg (to be published).
[3] S. Borowitz and N. Hamermesh, Phys. Rev. **74**, 1285 (1948).

V8. Variation of the Equilibrium Radius with Time in a Flux-Forced Field-Biased Betatron.* E. C. Gregg, Jr., *Case Institute of Technology.*—An analysis of the magnetic and electric circuits of a flux-forced field-biased betatron shows that the influence of imperfect feedback is equivalent to a time varying phase shift between flux and guiding field if the core is driven to saturation. For the case where core linearity is maintained, a constant phase shift results. Further, such an effect causes the true equilibrium radius to depend not only on the time in the acceleration cycle but also the relative injection phase (bias). Calculations show that for a phase shift of 30′, the variation in radius will range from -3.5 percent to $+6$ percent as the injection phase is varied from 0 to $-60°$. Typical operating conditions of the Case Institute 30-Mev betatron showed that a phase shift of 11′ should result while an actual phase shift of 30′ was measured. The difference is due to inner pole tip saturation which has a further effect of reducing the $H\sim 1/r^n$ range. Such considerations are of importance in proper gun and nominal equilibrium orbit locations for optimum performance.

* Supported in part by funds from the Research Corporation of New York and the Thomas White Fund of The Cleveland Foundation.

V9. Single Production of Mesons by γ-Rays Near Threshold. L. L. Foldy, *Case Institute of Technology.*—The cross section for single charged meson production through absorption of a γ-ray in a γ-ray-nucleon collision has been calculated to order g^2 in the charged scalar meson theory (scalar coupling) and charged pseudoscalar meson theory (pseudovector coupling). The nucleon was assumed

to be infinitely heavy thus restricting the validity of the results to γ-ray energies small compared to the nucleon rest energy and therefore to the energy region just above threshold. In the scalar theory the process can take place only through an intermediate state, but in the pseudoscalar theory, as a consequence of the currents associated with the emission of a meson by the nucleon, a direct transition from initial to final state is possible. Since the matrix element for the latter transition is not proportional to the meson momentum, the cross section in the pseudoscalar theory varies with a lower power of the energy above threshold ($\Delta E^{\frac{1}{2}}$) than does the cross section for the scalar theory ($\Delta E^{\frac{1}{2}}$), contrary to the usual behavior. Very near threshold the angular distribution of the mesons is proportional to $\sin^2\theta$ in the scalar theory and is uniform in the pseudoscalar theory. In both theories at energies 50 percent above threshold, the cross sections are of order 10^{-28} cm^2.

V10. Positon Theory. FREDERIK J. BELINFANTE, *Purdue University.*—Schroedinger's theory describing electrons by antisymmetric functions in configuration space follows from general quantized field theory by Fock's theory of second quantization. This theory is generalized so as to describe also positon-negaton theory in configuration space. The Schroedinger functions are products of separate antisymmetric functions for positons and for negatons, each necessarily a superposition of Slater-determinants of solutions of only one energy sign in field-free space. This holds in presence of external fields, too, as follows from Schwinger's relativistic splitting of the quantized electron $-\psi(x)$ in interaction representation into two parts. The hydrogen atom then shows a superposition of states with N positons and $(N+1)$ negatons, with non-vanishing probability for any N. Then $\psi(x_0)$ as operator changes a state with n negatons and p positons into a superposition of a state with one negaton removed at x_0, and another state with one positon added with wave-function $\Sigma\varphi_i(x)\varphi_i^*(x_0)$, where φ_i are positive energy solutions of Dirac's equation in field-free space. This distinction of states of either energy sign enables one to reformulate familiar subtraction formalisms and also to generalize Pauli's "*Handbuch* quantum-electrodynamics without gauge-dependent quantities" to positon theory, introducing suitable operators of pair creation and annihilation.

V11. Precision Gamma-Ray Wave-Length Measurements on I^{131} with the 2-Meter Curved Crystal Focusing Spectrometer.* DAVID A. LIND, JAMES BROWN, DAVID KLEIN, DAVID MULLER, AND JESSE DUMOND, *California Institute of Technology.*—Using a "carrier free" source of I^{131} five independent precision measurements of the 364 kev and two on the 80-kev lines had been made when news of the new disintegration scheme of F. Metzger and M. Deutsch[1] showing at least two additional lines reached us. In spite of source decay we were still able to obtain one precision measurement of the 284-kev line. The results are: measured wave-lengths in cm $(34.033\pm0.01)\cdot10^{-11}$, $(154.671\pm0.01)\cdot10^{-11}$, $(43.622\pm0.02)\cdot10^{-11}$; calculated energies in kev 364.18 ± 0.1, 80.133 ± 0.005, 284.13 ± 0.1. The sum of the quantum energies of the 284- and 80-kev lines agrees to a part in 4500 with that of the 364-kev line thus giving strong evidence for the correctness of Metzger and Deutsch's cascade scheme but unfavorable to a more recent four line double cascade proposal of G. E. Owen, D. Moe, and C. S. Cook.[2]

* Assisted by the joint program of the AEC and ONR.
[1] F. Metzger and M. Deutsch, Phys. Rev. **74**, 1640 (1948).
[2] G. E. Owen, D. Moe, and C. S. Cook, Phys. Rev. **74**, 1879 (1948).

V12. Diffraction of Slow Neutrons by Liquid D_2O. S. J. CZYZAK AND A. WATTENBERG, *Argonne National Laboratory.*—An investigation has been made of the relative differential scattering cross section of heavy water in an attempt to obtain information concerning interatomic distances in water. A curve has been obtained at 25°C covering a range in $(\sin\theta)/\lambda$ from 0.1 to 0.9. Only one pronounced maximum is present at a value of $(\sin\theta)/\lambda=0.16$ in agreement with previous x-ray diffraction work.[1]

[1] J. Morgan and B. E. Warren, J. Chem. Phys. **6**, 666 (1938).

SUPPLEMENTARY PROGRAMME

SP1. On the Scattering of Low Energy γ-Rays by Protons. L. L. FOLDY, *Case Institute of Technology.**—As a consequence of the coupling of the proton to the meson field one would expect that a proton could scatter a low energy γ-ray ($\hbar k \ll Mc^2$) through polarization of its meson charge cloud as well as through the usual Thomson scattering. The highest order term of this type in the transition matrix element would be expected to be of order $(g^2/\hbar c)(M/\mu)$ compared to the Thomson scattering term. An attempt to calculate this effect to the indicated order was made employing the charged scalar meson theory (scalar coupling) and the charged pseudoscalar meson theory (pseudovector coupling). In the scalar theory, the process may occur through two or three intermediate states, while in the pseudoscalar theory processes involving only one intermediate state are also possible. All quantities are finite in the scalar theory, but the matrix elements corresponding to processes with two and three intermediate states are equal and of opposite sign and lead to cancellation of any effect to this order. In the pseudoscalar theory the contributions arising from transitions involving an even and an odd number of intermediate states, now separately divergent, are again equal and of opposite sign leading again to cancellation of any effect. The cancellation in both cases occurs only after the summation over all intermediate momentum states for the meson. It is therefore difficult to attribute the null result in the two cases to some simple underlying selection rule.

* To be given after Session V if the Chairman rules that time permits.

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